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OBSERVATIONS ON THE PENNSYLVANIAN CRINOID *ENDELOCRINUS ARMATURA* (STRIMPLE)

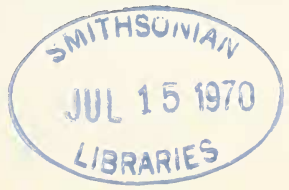
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ABSTRACT

Originally described as a species of *Delocrinus*, the Middle Pennsylvanian crinoid *Endelocrinus armatura* (Strimple) shows late attainment of biserial arm structure and has pits at the corners of the dorsal cup plates, both characteristic features of *Endelocrinus*. Unique ornamentation, predominately nodose at maturity, is traceable from pit-node structure in juveniles. Discovery of new specimens extends the geographic range of the species from Oklahoma to Ohio and Illinois.

Most species of Pennsylvanian inadunate crinoids are known only from dorsal cups; the arms are seldom preserved, either as a whole or in part. Consequently I have been fortunate in having at hand for the present study two specimens of a species of *Endelocrinus* in which most of the arms are preserved. This crinoid is characterized by unusual ornamentation, and in addition, one specimen represents a young, the other a mature stage of growth, permitting us to trace the ontogeny of the arms in at least one species of *Endelocrinus*.

For the opportunity to study these two specimens I am indebted to Dr. Richard D. Hoare of Bowling Green State University, Mr. James L. Murphy of Case Western Reserve University, and Dr. Porter Kier of the United States National Museum. I also wish to thank Dr. Kier for making the photographs from which the illustrations for this paper were taken.



SYSTEMATIC PALEONTOLOGY

Family ERISOCRINIDAE Miller, 1889

Genus ENDELOCRINUS Moore and Plummer, 1940

ENDELOCRINUS ARMATURA (Strimple), 1949

Plate 1, figs. 1-6

Delocrinus armatura Strimple, 1949, Paleontographica Americana, v. 3, pt. 1, p. 18, pl. 3, figs. 3, 6.

Diagnosis: A large species of *Endelocrinus* (diameter of dorsal cup at maturity exceeding 19 mm); form ratio 0.37 to about 0.41. Ornamentation distinctive, with crown plates characterized by pits and nodes; pits dominant over nodes at juvenile stage, nodes predominant and granulose ornamentation characteristic of mature stage; initiation of biseriality on third to fifth secundibrachs at cup width of about 19 mm, with "normal biseriality" attained on seventh or eighth secundibrachs. Primibrachs without spines.

Occurrence: Middle Pennsylvanian (Oklahoma, Ohio, and Illinois).

The holotype of this species was derived from the Pumpkin Creek Limestone, Dornick Hills Group, Pennsylvanian, in Love County, Oklahoma.

In the original description of the holotype, U.S.N.M. S4689, Strimple did not note the characteristic *Endelocrinus* pits at the angles of the plates of the dorsal cup and attributed this species to *Delocrinus*. At the same time he failed to indicate the unique ornament of the cup, stating only that the ornamentation "consists of irregular swollen tubercles which are more pronounced on the RR than the BB."

Of the two specimens which I am attributing to *Endelocrinus armatura*, the one which approaches nearest to the holotype in size and ornament is in the collection of the United States National Museum and was collected by Mr. James L. Murphy. It consists of a dorsal cup with the greater part of the arms and a portion of the stem attached. This specimen, U.S.N.M. 166578, was taken from the Putnam Hill Limestone of the Allegheny Group, Pennsylvanian, in the NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 13, Springfield Twp., Muskingum County, Ohio. The Putnam Hill Limestone crops out about 200 feet west of U.S. Route 22 on a small knoll west of a shopping center designated on the Zanesville West 7.5' Quadrangle.

Because Strimple's holotype has suffered damage from weathering, breakage and dislocation of plates, it is difficult to make strictly comparable measurements of the two specimens. Measurements of height and width of U.S.N.M. S4689 are at best approximate, and I believe that the form ratio is closer to 0.41 than Strimple's finding of 0.45. The Ohio specimen is a larger and presumably older individual, with a form ratio of 0.37. Breakage and distortion may account to some extent for the apparent differences in width and depth of the basal impressions of the two specimens, but the holotype actually appears to have a wider and shallower concavity. The proportions of the radials and basals of the two dorsal cups are in close accord, and the cups are also similar in the outward flare of their radials and in showing channels along the interrarial sutures. Despite the variations noted, the remarkable agreement in peculiar ornamentation argues strongly for the specimens being conspecific.

As Strimple noted, the most prominent feature of the ornamentation of the cup is large nodes or tubercles. These are irregularly distributed for the most part, although they tend toward a festoon-like arrangement below the forefacets of the radials. The nodes are more distinct on the radials, but they are found on the basals also. However, the most striking ornamental feature of these dorsal cups consists in angular depressions associated with the nodes and connected by a network of slender and shallow canals. The depressions are most numerous on the basals, but they also occur along with the canals, on the radials. In the Ohio specimen, the proximal region of the basal cirlet is more extensively ornamented. A single large, less angular depression occupies most of the surface of the portion of anal X that rises above the summit of the cup, and in U.S.N.M. 166578, the Ohio specimen, a similar depression shows on the overlying tube plate. In this specimen there also appear to be traces of incipient granular structure on portions of the cup, but none is showing within the basal impression.

Unfortunately, the holotype of *Endelocrinus armatura* consists of no more than the dorsal cup with a portion of the stem attached. The Ohio specimen, U.S.N.M. 166578, preserves, in contrast, a considerable portion of the arms. A glance at the arms leaves no doubt that this is a very young individual. The height of the axillary first

primibrachs and the markedly high and quadrangular proximal secundibrachs are evidence of this.

The primibrachs of this young specimen display the same ornamentation as the dorsal cup, with variations. The depressions are more rounded and predominate over the nodes in diameter. There are one or two crater-like impressions on each flank of a primibrach. Canals are also present. The primibrachs lack spines. Near the distal tip of the primibrach of the A ray there is a depression from the floor of which a small node originates. The nodes are prominent and little trace of the depressions remains in the primibrachs of rays C, D, and E. The primibrach of the B ray is worn at this place, but appears to have borne a small node in the depression.

For the most part, the secundibrachs remain quadrangular up to the sixth or seventh, with long and short sides alternating. Distally they become triangular or cuneate, and the initiation of the biserial arrangement is apparent on the eighth or ninth, where the cuneate plate fails to extend across the full width of the arm. None of the arms are complete; there appear to be 13 secundibrachs on one of them.

A few of the articular surfaces of the secundibrachs are showing, but some of their details are obscure. The outer ligament area is faintly denticulate and the outer ligament pit slitlike. The transverse ridge is indistinct. The intermuscular notch is V-shaped and, together with the intermuscular furrow, divides the two large flexor muscle areas.

The sides of the secundibrachs show shallow hollows, indicating that even at this early stage some interlocking of the arms was possible.

EXPLANATION OF PLATE 1

(All figures $\times 2$)

Fig. 1. *Endelocrinus armatura* (Strimple), holotype, U.S.N.M. S4689, from the Pumpkin Creek Limestone, Dornick Hills Group, Love County, Oklahoma. a, basal view and b, posterior view of the dorsal cup.

Fig. 2. *Endelocrinus armatura* (Strimple), hypotype, U.S.N.M. 166578, from the Putnam Hill Limestone, Allegheny Group, Muskingum County, Ohio. a, basal view and b, posterior view of the crown.

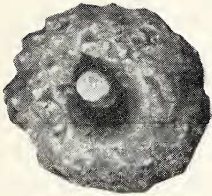
Fig. 3. *Endelocrinus armatura* (Strimple), hypotype, B.G.S.U. 2540, from the shale above the No. 6 Coal, Kewanee Group, St. Clair County, Illinois. a, basal view and b, posterior view of the crown.



1 a



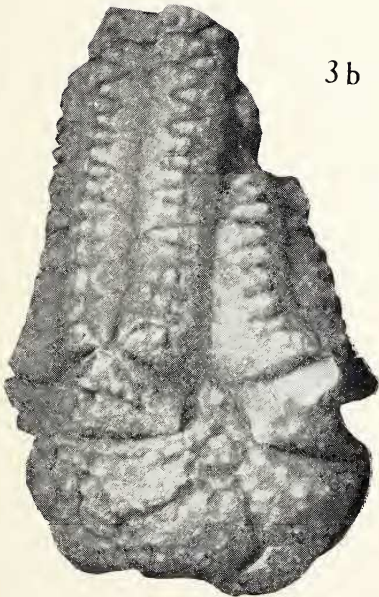
1 b



2 a



2 b



3 b



3 a

The specimen preserves a few stout pinnulars, but no complete pinnules.

Depressions and nodes also characterize the ornamentation of the secundibrachs, but only a few of these plates show canals. The first secundibrach bears more prominent nodes than those distal to it, but for the most part lacks the order in arrangement of depressions and nodes that exists in the secundibrachs that follow. This, in its simplest form, consists of a diamond-shaped depression shared by pairs of secundibrachs along the length of the arm, extending from underlying to overlying plates, with its lateral angles at their sutural junctions. The vertical angles of the depressions are usually marked by nodes or incipient nodes. There are variations of this pattern, but as the secundibrachs approach or attain the cuneate stage, the plates usually bear a single prominent node nearly marking the midline of the arm.

Here and there on the arms there appear to be traces of granular ornamentation, but it is not well defined.

The second specimen which I am referring to *Endelocrinus armatura* was collected from the shale over the No. 6 Coal of the Carbondale Formation, Kewanee Group, Pennsylvanian, at the Midwest Coal Company mine near Millstadt, St. Clair County, Illinois. It was found by Miss Dorothy Lalonde, a student of Dr. Richard D. Hoare of Bowling Green State University, who in turn submitted the crinoid to me for study.

This specimen (B.G.S.U. 2540) is part of a crown with portions of seven arms attached. Part of the stem is also preserved. On the anterior side the arm and cup plates are dislocated and mashed. An estimated width of about 19.5 mm for the dorsal cup indicates that we are dealing with a large species of *Endelocrinus*. The form ratio was probably about 0.40.

The basal impression is relatively deeper than that of the holotype of *Endelocrinus armatura*, but apparently less so than that of the juvenile specimen from Ohio. The Illinois specimen is also closer in accord with the holotype in showing less pit and node ornamentation in the proximal portion of the basal circlet; the pits and nodes are most evident in areas adjoining the distal reaches of the interbasal sutures, although they are also present on other parts of the distal extensions of the basals.

In this mature specimen the nodes predominate over the pits.

Growth of the nodes has eliminated the canals, and modified the surface to such an extent that only one of the characteristic *Endelocrinus* pits, that of the DE interray, is still evident. Nodes occupy the areas that show as pits in anal X and the overlying tube plate of the Ohio specimen, although the outlines of the pits are still apparent. The entire cup bears coarsely granulose ornament, which extends to the proximal region of the basals.

The primibrachs, in keeping with the age of this large specimen, are relatively of less height and greater width than in the juvenile specimen from Ohio. What remain of the craterlike depressions shown on the primibrachs of that juvenile individual appear only as irregular borders separating a lumpy mass of nodes from the relatively smooth lateral flanks of the plates. The most distinct of these nodes are those at tips of the primibrachs, which are relatively much larger than those characterizing the juvenile specimen and much more irregular in outline. No traces of the canals remain on the primibrachs.

The secundibrachs, for the most part, remain quadrangular up to and including the third or fourth, although in one arm only the first two secundibrachs are quadrangular. Triangular (cuneate) plates succeed the quadrangular secundibrachs, and also mark the initiation of biseriality, for these plates fail to extend the full width of the arm. However, "normal biseriality," as interpreted by Grabau (1903, p. 290) apparently was not attained before the seventh or eighth secundibrach. The arms are not complete; there are 18 secundibrachs present in each of the two with the most length preserved, and these arms must have been at least a third longer originally.

Some of the biserial secundibrachs show the articular surfaces, which are fairly typical for *Endelocrinus*. There are indications of the external ligament area, transverse ridge, intermuscular notch and intermuscular furrow. The principal flexor muscle scars are fairly evident, but the minor scars are rather obscure.

The interlocking structures of the arms are traceable not only on the sides of the arms, but also in external view, and the concave borders of one arm are seen to mesh with the convex borders of the adjacent arm with remarkable precision.

Along the midline of the arm each secundibrach bears a single prominent node—the feature noted in the juvenile specimen at the

cuneate stage. These nodes occupy what were the diamond-shaped depressions in the secundibrachs of the young crinoid. However, although the nodes on the secundibrachs, as well as on other parts of the crown of the more mature specimen have supplanted the pits and other depressions, it is still possible to find indications of the former structure in these secundibrachs.

Coarse granulose ornamentation, such as that found on the dorsal cup, also characterizes the arms of the Illinois specimen.

Linear measurements, in millimeters, of the holotype of *Endelocrinus armatura* and the two specimens which I am referring to the species are as follows:

	Holotype U.S.N.M. S4689	Hypotype U.S.N.M. 166578	Hypotype B.G.S.U. 2540
Height dorsal cup	4.6*	4.6	8.2*
Width dorsal cup	11.1*	12.3	19.5*
H/W	0.41*	0.37	0.40*
Width basal concavity	5.7*	5.0	8.4
Height basal concavity	—	1.8+	2.3+
Width stem	1.8	1.9	2.9
Length basal	3.6**	4.0	6.5
Width basal	3.9	4.2	7.7
Length radial	3.6	4.0	6.0
Width radial	5.9	6.5	8.6
Length suture between BB	2.7**	2.7	4.7
Length suture between RR	2.3	2.4	3.4
Length anal X	2.2	3.6	3.9
Width anal X	2.0	2.7	3.6
Length first tube plate	—	1.4	2.1
Width first tube plate	—	1.7	2.4
First primibrachs:			
A, length	—	4.9	5.7**
A, width	—	5.8	8.5**
B, length	—	3.8	4.8**
B, width	—	5.9	7.9
C, length	—	4.9	5.3
C, width	—	5.7	8.0
D, length	—	5.0	5.8
D, width	—	5.5	8.2
E, length	—	4.0	4.7
E, width	—	5.8	8.4

*Estimated

**Approximate

DISCUSSION

The unique major ornament of the three crinoid specimens treated here, coupled with the fact that it can be traced step by step from juvenile to mature stages of growth, constitutes the strongest argument for regarding the three specimens as conspecific. Greater size and presence of definite granular ornamentation characterize the mature individual, B.G.S.U. 2540, and there appear to be variations in depth and width of the basal impression among the three specimens involved, but I have given these characters full consideration and fail to find them grounds for specific or subspecific distinction.

In a previous paper (Burke, 1967) I suggested that fully biserial arm structure may have been attained late in life in various species of *Endelocrinus*. Study of these specimens of *Endelocrinus armatura* and additional undescribed material representative of *Endelocrinus* further supports this suggestion. However, biseriality in the arms of B.G.S.U. 2540 has progressed at least to the extent that I have observed the condition in certain presumed mature specimens of *Delocrinus*. Nevertheless, biserial arm structure must have been realized at a very early stage of growth in most species of *Delocrinus*—possibly even before the arm segments were sufficiently developed to remain associated after the death of the individual, otherwise crowns showing earlier stages in attainment of biseriality would be known.

There is, however, one species, either a *Delocrinus* or a form closely related to that genus, which may compare with *Endelocrinus* in delayed acquirement of biseriality. Strimple and Knapp (1966, pl. 36, figs. 1, 2) have illustrated the crown of a specimen which they attribute to "*Diphuicrinus*" *croneisi* Moore and Plummer, from which they conclude, because the arms are uniserial, that "*Diphuicrinus*" is distinct from *Delocrinus*. However, the distal secundibrachs of the crown appear to be cuneate, which strongly suggests that the individual might have eventually developed biserial arm structure. Furthermore, if Strimple and Knapp are correct in their identifications, this is presumably a young individual; the diameter of the dorsal cup is given as 21 mm, that of the holotype of the species as 24 mm; cup diameters of two other specimens, however, are noted as 31 and 43 mm respectively (*ibid.*, p. 313). If the latter two specimens actually pertain to the species, there would

appear to be the possibility that in attaining such size "*Diphocrinus*" *croneisi* might also have acquired some degree of biserial arm structure.

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